§33. FDTD Simulation of Millimeter-wave Corrugated Waveguides with Cylindrical Symmetry Model

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Introduction In this study, we estimate influences of manufacturing errors of the corrugated circular waveguide by numerical simulation using finite-difference time-domain (FDTD) method.

Simulation Model In FDTD method, the 3D Maxwell equation is solved numerically, in the perfect matched layer (PML) boundary condition, for the same situation as the experimental configuration. However it is difficult to solve this equation directly in 3D environment since data size becomes too big and simulation time is too long. For reducing these costs, we uses 2D model [1].

Figure 1 shows corrugate waveguide geometry in this simulation. The walls of waveguide are perfect conductor and the boundary of both side of waveguide is PML boundary. The actual material is Aluminum; however it is difficult to calculate with Aluminum wall because the skin depth of Aluminum is too thin and as the result of that minimum lattice size is too small. The inside region of waveguide is vacuum.

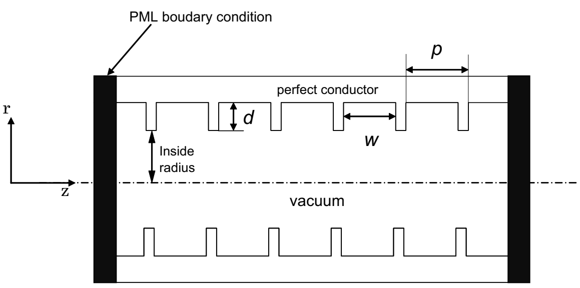

Fig. 1: Simulation model of corrugated waveguide. w is width of a groove, d is depth of a groove and p is pitch.

Result Table I shows parameters in this simulation.

Table I: Parameters in the corrugated waveguide simulation

Element	Parameter
Input source frequency	84 GHz
Wave length	3.57 mm
Inside radius	15.9 mm
Width of groove	1.0 mm
Amplitude of error	0.1, 0.3, 0.5 mm, no error
Pitch of error	10, 50, 100 mm
Time step	8.3e-14 sec
Total simulation time	16.7 nsec
Lattice size	0.05 mm
PML thickness	1.0 mm

For estimating influence of manufacturing error, shape error described in eq. (1) is appended.

$$d^{error} = d + a\sin(\frac{2\pi}{p^{error}}z), \quad (1)$$

where a is amplitude of error and p^{error} is period of error. We simulated in some parameters of a, p^{error} and d and inputted transverse electric mode (TM01 mode, electromagnetic field is constant in θ-direction) wave. For estimating simulation results and turbulence, we introduce the correlation factor eq. (2).

$$r = \frac{\sum_{i=1}^{n}(E_i^{in} - \bar{E^{in}})(E^{out} - \bar{E_i^{out}})}{\sqrt{\sum_{i=1}^{n}(E_i^{in} - \bar{E^{out}})^2}\sqrt{\sum_{i=1}^{n}(E_i^{in} - \bar{E^{out}})^2}}, \quad (2)$$

where r is correlation factor, n is the number of data in r-direction and E^{in} and E^{out} means value of electric field in the input and output position. The distance between input and output position is 125 mm and 35 waves are included in this area. Therefore the phase is the same both in the input and output position.

Figure 2 shows the result of manufacturing error. These results show that the worse the error is, the smaller the correlation factor is. This result can be understood intuitively. However, this estimation is just compared with error and shape change of electric field, thus it is necessary to compare with experimental results.

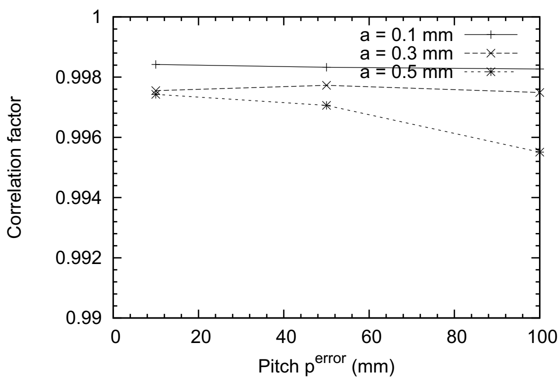

Fig. 2: Dependency of pitch p. $d =$ 0.75 mm.

1) Tamura, Y. et al. : Journal of Physics: Conference Series (2013) 410.